International Journal of Remote Sensing
Vol. 26, No. 19, 10 October 2005, 4239–4264

Validation of the MODIS active fire product over Southern Africa with ASTER data

JEFFREY T. MORISETTE*†, LOUIS GIGLIO†, IVAN CSISZAR‡ and CHRISTOPHER O. JUSTICE‡

†NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

‡Department of Geography, University of Maryland, 2181 LeFrak Hall, College Park, MD 20742, USA

This paper describes the use of high-spatial-resolution ASTER data to determine the accuracy of the moderate-resolution MODIS active fire product. Our main objective was to develop a methodology to use ASTER data for quantitative evaluation of the MODIS active fire product and to apply it to fires in southern Africa during the 2001 burning season. We utilize 18 ASTER scenes distributed throughout the Southern Africa region covering the time period 5 August 2001 to 6 October 2001. The MODIS fire product is characterized through the use of logistic regression models to establish a relationship between the binary MODIS 'fire'/'no fire' product and summary statistics derived from ASTER data over the coincident MODIS pixel. Probabilities of detection are determined as a function of the total number of ASTER fires and Moran's *I*, a measure of the spatial heterogeneity of fires within the MODIS pixel. The statistical analysis is done for versions 3 and 4 of the MODIS fire-detection algorithm. It is shown that the algorithm changes have a positive effect on the fire-product accuracy.

1. Introduction

The objective of the Southern Africa Fire and Atmosphere Research Initiative (SAFARI) is to investigate the Earth–atmosphere–human interaction through an extensive field campaign, including ground-, air- and space-based observations of various biogeophysical and biogeochemical processes (Swap *et al.* 1998). Among these processes is the emission of gases and particulate matter into the atmosphere by natural and agricultural biomass burning. A critical part in the process of understanding the influence of fire on the atmosphere is to have accurate and reliable information on the timing of fires and their location.

The most practical way of obtaining large-scale maps of fire occurrences is to use moderate- to high-resolution radiometers on board satellites (Justice and Korontzi 2001). For a long period, the Advanced Very High Resolution Radiometer (AVHRR) on board the polar orbiter NOAA satellites was the only instrument that provided observations of the spatial distribution of fire hot spots on a global scale with relatively high temporal frequency. Additional instruments on board other platforms began to be exploited for fire monitoring in the following decade, including the Geostationary Orbiting Environmental Satellite (GOES), Visible Infrared Spin Scan Radiometer Atmospheric Sounder (VAS) (Prins and Menzel

*Corresponding author. Email: jeff.morisette@nasa.gov

International Journal of Remote Sensing
ISSN 0143-1161 print/ISSN 1366-5901 online © 2005 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/01431160500113526

1992), the GOES Imager (Menzel and Prins 1996), the Defense Meteorological Satellite Program (DMSP), Operational Linescan System (OLS) (Elvidge and Baugh 1996), the Along Track Scanning Radiometer (ATSR) (Arino and Rosaz 1999), the Tropical Rainfall Measuring Mission (TRMM) and the Visible and Infrared Scanner (VIRS) (Giglio *et al.* 2000). However, these instruments' characteristics are not optimal for fire detection. Nevertheless, AVHRR data have been successfully used for mapping fires during the SAFARI 1992 campaign, using a multi-spectral and contextual algorithm appropriately tuned for local conditions (Justice *et al.* 1996).

The Moderate Resolution Imaging Spectroradiometer (MODIS; Kaufman *et al.* 1998) is a 36-band instrument with substantially improved capabilities for fire mapping as compared with the AVHRR. The first MODIS sensor is onboard the Terra satellite, which was launched in December of 1999 and has a daytime local overpass of about 10.30 a.m. The second MODIS sensor is onboard the Aqua satellite, launched in May 2002, with a 1.30 p.m. daytime overpass. One of the land products derived from the MODIS sensor is a pixel-resolution fire mask, separated into files representing 5 min of image acquisition along a given swath (Justice *et al.* 2002a). The increased saturation temperatures of the 1 km resolution 3.9 μm and 11 μm sensors decrease the ambiguities leading to false alarms or omission errors typical of the AVHRR-based fire products (Giglio *et al.* 2003). The first MODIS sensor is onboard the Terra satellite, launched in December of 1999, and has a daytime local overpass of about 10.30 a.m. The second MODIS sensor is onboard the Aqua satellite, launched in May 2002, and has a 1.30 p.m. daytime overpass. The main objective of this paper is to develop a methodology to use ASTER data for quantitative evaluation of the MODIS active fire product and to apply it to fires in Southern Africa during the 2001 burning season, concentrating only on imagery from the daytime overpass.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (Yamaguchi *et al.* 1998), also onboard the Terra satellite, provides near-nadir view measurements in four visible and near-infrared bands between 0.52 and 0.86 μm, six shortwave infrared (SWIR) bands between 1.6 and 2.43 μm, and five thermal infrared (TIR) bands between 8.125 and 11.65 μm at 15, 30 and 90 m resolutions, respectively. The coincident high-resolution, multi-spectral measurements within a ~60 km swath near the centre of the MODIS swath provide a unique opportunity to analyse the fine-scale features within the MODIS pixels, such as active fires.

Figure 1 is an ASTER band 9 (2.4 μm) grey-scale image of a large fire complex in Namibia. Overlain are the MODIS 1 km footprints, with white boxes denoting pixels flagged as fires by the MODIS version 3 fire product. The superior representation of the fine-scale details of the fire by ASTER is obvious. Omission and commission errors from MODIS are also visible. For example, the MODIS algorithm failed to detect distinct fire fronts within pixels, particularly in the upper part of the image. Also, some pixels with no fire signal from ASTER were flagged by the MODIS algorithm as containing fire. These commission and omission errors underline the limitations of the MODIS fire algorithm and the need for quantification of its accuracy.

The input data for this study are presented in section 2. In section 3, a procedure to create binary ASTER fire masks within the MODIS footprints and a method for their statistical comparison with the MODIS product are described. Results of the analysis are presented in section 4 for both versions 3 and 4 of the MODIS fire-detection algorithm. The statistical analysis is followed by a discussion of the results in section 5.